# EXHIBIT D

# Exhibit C

# Exhibit C - U.S. Patent No. 10,368,361 ("'361 Patent")

Accused Instrumentalities: cellular base stations that support 3GPP NG-RAN supporting directional Supplementary Uplink (SUL) and/or Bandwidth Adaptation functionality, and all versions and variations thereof since the issuance of the asserted patent. Based upon publicly available information and without the benefit of discovery in this case, these base stations include, but are not limited to the following products sold by Nokia, Ericsson, and Samsung:

**Nokia:** AirScale base station, AirScale radio and baseband, AirScale 5G mMIMO base station, ReefShark System on Chip and all products containing the same, AirScale Osprey, AirScale Habrok, AirScale mRRH, AirScale pRRH, AirScale 4.5G Pro RRH, AirScale sHUB, FZHR, AHBOA, FSIH, FHFB, AZHL, AAFIA, 32TRX, and 64TRX.

**Ericsson:** 5G AIR products, 5G Baseband products, 5G Radio products, 5G Antenna products, AIR 1279, AIR 3218, AIR 3219, AIR 3229, AIR 3239, AIR 3246, AIR 3258, AIR 3268, AIR 3283, AIR 6419, AIR 6428, AIR 6468, AIR 6476, AIR 6488, Interleaved AIR, Baseband 5216, Baseband 6502, Baseband 6648, 5G Radio Dot, Radio 4407, Radio 4408, Radio 4412, Radio 4418, Radio 4485, Radio 4490, Radio 8808, Radio 8863, Antenna 4600, Antenna 4602, Antenna 5500, and Antenna 6600.

**Samsung:** 5G base stations, 4T4R CBRS Radio, 32T32R Radio, 64T64R Radio, C-Band Radio, CDU50, One Antenna Radio, Link Hub, and Link HubPro.

## Claim 10

| Claim 10 | Public Documentation |
|---|---|
| [10pre] A wireless base station for a wireless communication network, the wireless base station comprising: | To the extent the preamble is found to be limiting, the Accused Instrumentalities comprise a wireless base station for a wireless communication network.<br><br>For example, the Accused Instrumentalities include an NG-RAN node, such as a gNB, which performs wireless communication in accordance with NG-RAN architecture. This structure is described, for example, in 3GPP standards documents such as TS 38.104 v15.5.0, TS 38.101-1 v15.5.0, TS 38.300 V2.0.0, and associated documents, which describe aspects of the operations associated with components of the Accused Instrumentalities. |

| Claim 10 | Public Documentation |
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## 4.1 Overall Architecture

An NG-RAN node is either:

- a gNB, providing NR user plane and control plane protocol terminations towards the UE; or
- an ng-eNB, providing E-UTRA user plane and control plane protocol terminations towards the UE.

The gNBs and ng-eNBs are interconnected with each other by means of the Xn interface. The gNBs and ng-eNBs are also connected by means of the NG interfaces to the 5GC, more specifically to the AMF (Access and Mobility Management Function) by means of the NG-C interface and to the UPF (User Plane Function) by means of the NG-U interface (see TS 23.501 [3]).

NOTE: The architecture and the F1 interface for a functional split are defined in TS 38.401 [4].

The NG-RAN architecture is illustrated in Figure 4.1-1 below.

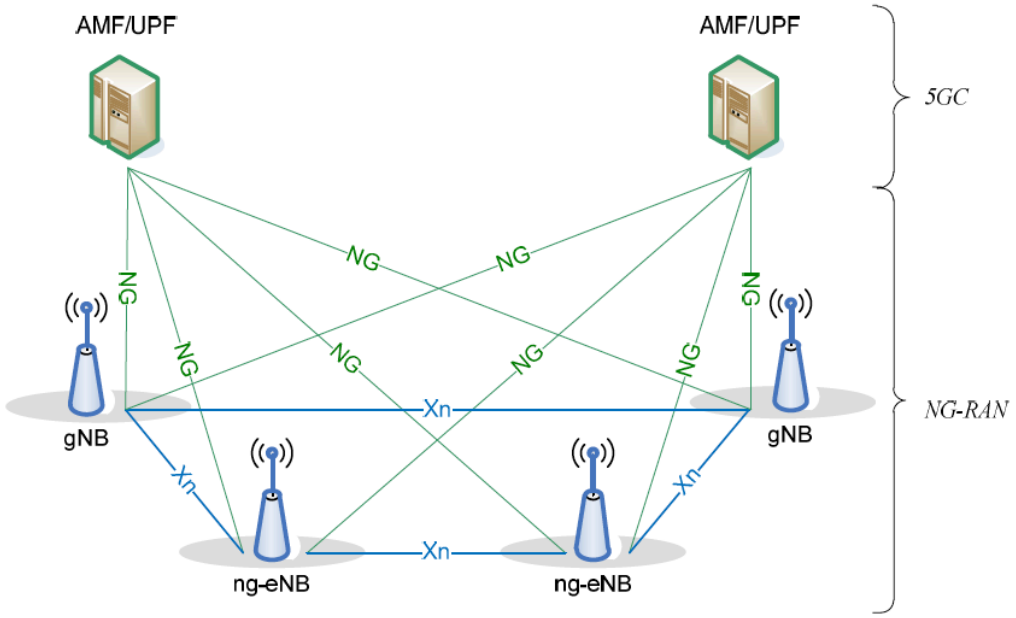


**Figure 4.1-1: Overall Architecture**

| Claim 10 | Public Documentation |
|---|---|
| | (3GPP TS 38.300 v17.2.0, § 4.1) |
| [10a] a quality status module configured to determine a respective quality status of a first frequency spectrum resource and a second frequency spectrum resource, wherein each of the first frequency spectrum resource and the second frequency spectrum resource are associated with an air interface that is available for use by the wireless base station for an uplink channel or a downlink channel; | The Accused Instrumentalities comprise a quality status module configured to determine a respective quality status of a first frequency spectrum resource and a second frequency spectrum resource, wherein each of the first frequency spectrum resource and the second frequency spectrum resource are associated with an air interface that is available for use by the wireless base station for an uplink channel or a downlink channel.<br><br>For example, the Accused Instrumentalities include a particular hardware or software module to perform radio resource management and related functions, including respective quality determinations for each frequency resource within the NR air interface used by the base station for uplink and/or downlink. |

| Claim 10 | Public Documentation |
|---|---|
| | 4.2 Functional Split<br><br>The **gNB** and ng-eNB host the following functions:<br><br>- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);<br>- IP header compression, encryption and integrity protection of data;<br>- Selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE;<br>- Routing of User Plane data towards UPF(s);<br>- Routing of Control Plane information towards AMF;<br>- Connection setup and release;<br>- Scheduling and transmission of paging messages;<br>- Scheduling and transmission of system broadcast information (originated from the AMF or OAM);<br>- Measurement and measurement reporting configuration for mobility and scheduling;<br>- Transport level packet marking in the uplink;<br>- Session Management;<br>- Support of Network Slicing;<br>- QoS Flow management and mapping to data radio bearers;<br>- Support of UEs in RRC_INACTIVE state;<br>- Distribution function for NAS messages;<br>- Radio access network sharing;<br>- Dual Connectivity;<br>- Tight interworking between NR and E-UTRA.<br><br>*References:*<br>(3GPP TS 38.300 V2.0.0 (2017-12), § 4.2) |

| Claim 10 | Public Documentation |
|---|---|

**Table 5.2-1: NR *operating bands* in FR1**

| NR *operating band* | Uplink (UL) *operating band* BS receive / UE transmit $F_{UL\_low}$ – $F_{UL\_high}$ | Downlink (DL) *operating band* BS transmit / UE receive $F_{DL\_low}$ – $F_{DL\_high}$ | Duplex Mode |
|---|---|---|---|
| n1 | 1920 MHz – 1980 MHz | 2110 MHz – 2170 MHz | FDD |
| n2 | 1850 MHz – 1910 MHz | 1930 MHz – 1990 MHz | FDD |
| n3 | 1710 MHz – 1785 MHz | 1805 MHz – 1880 MHz | FDD |
| n5 | 824 MHz – 849 MHz | 869 MHz – 894 MHz | FDD |
| n7 | 2500 MHz – 2570 MHz | 2620 MHz – 2690 MHz | FDD |
| n8 | 880 MHz – 915 MHz | 925 MHz – 960 MHz | FDD |
| n12 | 699 MHz – 716 MHz | 729 MHz – 746 MHz | FDD |
| n20 | 832 MHz – 862 MHz | 791 MHz – 821 MHz | FDD |
| n25 | 1850 MHz – 1915 MHz | 1930 MHz – 1995 MHz | FDD |
| n28 | 703 MHz – 748 MHz | 758 MHz – 803 MHz | FDD |
| n34 | 2010 MHz – 2025 MHz | 2010 MHz – 2025 MHz | TDD |
| n38 | 2570 MHz – 2620 MHz | 2570 MHz – 2620 MHz | TDD |
| n39 | 1880 MHz – 1920 MHz | 1880 MHz – 1920 MHz | TDD |
| n40 | 2300 MHz – 2400 MHz | 2300 MHz – 2400 MHz | TDD |
| n41 | 2496 MHz – 2690 MHz | 2496 MHz – 2690 MHz | TDD |
| n50 | 1432 MHz – 1517 MHz | 1432 MHz – 1517 MHz | TDD |
| n51 | 1427 MHz – 1432 MHz | 1427 MHz – 1432 MHz | TDD |
| n65 | 1920 MHz – 2010 MHz | 2110 MHz – 2200 MHz | FDD |
| n66 | 1710 MHz – 1780 MHz | 2110 MHz – 2200 MHz | FDD |
| n70 | 1695 MHz – 1710 MHz | 1995 MHz – 2020 MHz | FDD |
| n71 | 663 MHz – 698 MHz | 617 MHz – 652 MHz | FDD |
| n74 | 1427 MHz – 1470 MHz | 1475 MHz – 1518 MHz | FDD |
| n75 | N/A | 1432 MHz – 1517 MHz | SDL |
| n76 | N/A | 1427 MHz – 1432 MHz | SDL |
| n77 | 3300 MHz – 4200 MHz | 3300 MHz – 4200 MHz | TDD |
| n78 | 3300 MHz – 3800 MHz | 3300 MHz – 3800 MHz | TDD |
| n79 | 4400 MHz – 5000 MHz | 4400 MHz – 5000 MHz | TDD |
| n80 | 1710 MHz – 1785 MHz | N/A | SUL |
| n81 | 880 MHz – 915 MHz | N/A | SUL |
| n82 | 832 MHz – 862 MHz | N/A | SUL |
| n83 | 703 MHz – 748 MHz | N/A | SUL |
| n84 | 1920 MHz – 1980 MHz | N/A | SUL |
| n86 | 1710 MHz – 1780 MHz | N/A | SUL |

(3GPP TS 38.104 V15.5.0 (2019-03), Table 5.2-1).

In the example highlighted above, a non-limiting first frequency spectrum resource is the Supplementary UpLink (SUL) band 80, and a non-limiting second frequency spectrum resource is the bi-directional TDD band 78.

| Claim 10 | Public Documentation |
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## 5.1 General

The channel arrangements presented in this clause are based on the *operating bands* and *BS channel bandwidths* defined in the present release of specifications.

NOTE: Other *operating bands* and *BS channel bandwidths* may be considered in future releases.

Requirements throughout the RF specifications are in many cases defined separately for different frequency ranges (FR). The frequency ranges in which NR can operate according to the present version of the specification are identified as described in table 5.1-1.

**Table 5.1-1: Definition of frequency ranges**

| Frequency range designation | Corresponding frequency range |
|---|---|
| FR1 | 410 MHz – 7125 MHz |
| FR2 | 24250 MHz – 52600 MHz |

(3GPP TS 38.104 V15.5.0 (2019-03), § 5.1 and Table 5.1)

**Table 5.2C-1: Operating band combination for SUL in FR1**

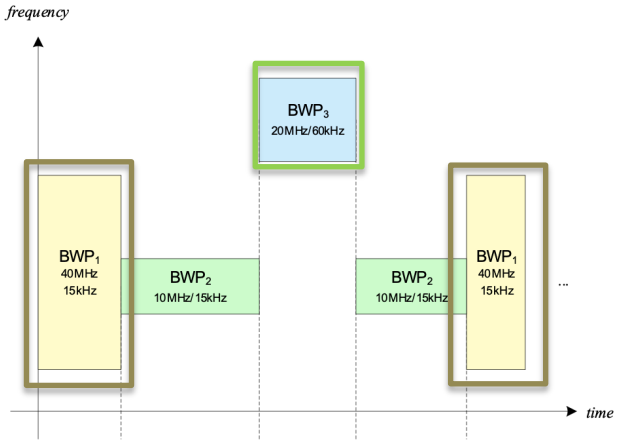
| NR Band combination for SUL | NR Band (Table 5.2-1) |
|---|---|
| SUL_n78-n80[2] | n78, n80 |
| SUL_n78-n81[2] | n78, n81 |
| SUL_n78-n82[2] | n78, n82 |
| SUL_n78-n83[2] | n78, n83 |
| SUL_n78-n84[2] | n78, n84 |
| SUL_n78-n86[2] | n78, n86 |
| SUL_n79-n80[2] | n79, n80 |
| SUL_n79-n81[2] | n79, n81 |
| NOTE 1: If a UE is configured with both NR UL and NR SUL carriers in a cell, the switching time between NR UL carrier and NR SUL carrier is 0 us.<br>NOTE 2: For UE supporting SUL band combination simultaneous Rx/Tx capability is mandatory. | |

(3GPP TS 38.101-1 V15.5.0 (2019-03), Table 5.2C-1.)

As shown in these examples, band 80 (non-limiting example of first frequency resource) supports uplink transmission only, while band 78 (non-limiting example of second frequency resource) in TDD supports both uplink and downlink transmissions.

| Claim 10 | Public Documentation |
|---|---|
| | As a further and/or alternative example, the Accused Instrumentalities perform radio resource management and related functions, including respective quality determinations for each frequency resource within the NR air interface used by the base station for uplink and/or down-link to support Bandwidth Adaptation:<br><br>**7 RRC**<br><br>**7.1 Services and Functions**<br><br>The main services and functions of the RRC sublayer include:<br>- Broadcast of System Information related to AS and NAS;<br>- Paging initiated by 5GC or NG-RAN;<br>- Establishment, maintenance and release of an RRC connection between the UE and NG-RAN including:<br>  - Addition, modification and release of carrier aggregation;<br>  - Addition, modification and release of Dual Connectivity in NR or between E-UTRA and NR.<br>- Security functions including key management;<br>- Establishment, configuration, maintenance and release of Signalling Radio Bearers (SRBs) and Data Radio Bearers (DRBs);<br>- Mobility functions including:<br>  - Handover and context transfer;<br>  - UE cell selection and reselection and control of cell selection and reselection;<br>  - Inter-RAT mobility.<br>- QoS management functions;<br>- UE measurement reporting and control of the reporting;<br>- Detection of and recovery from radio link failure;<br><br>(3GPP TS 38.300 v17.2.0, § 7.1) |

| Claim 10 | Public Documentation |
|---|---|
| | **7.8 Bandwidth Adaptation**<br><br>To enable BA on the PCell, the gNB configures the UE with UL and DL BWP(s). To enable BA on SCells in case of CA, the gNB configures the UE with DL BWP(s) at least (i.e. there may be none in the UL). For the PCell, the initial BWP is the BWP used for initial access. For the SCell(s), the initial BWP is the BWP configured for the UE to first operate at SCell activation.<br><br>In paired spectrum, DL and UL can switch BWP independently. In unpaired spectrum, DL and UL switch BWP simultaneously. Switching between configured BWPs happens by means of RRC signalling, DCI, inactivity timer or upon initiation of random access. When an inactivity timer is configured for a serving cell, the expiry of the inactivity timer associated to that cell switches the active BWP to a default BWP configured by the network. There can be at most one active BWP per cell, except when the serving cell is configured with SUL, in which case there can be at most one on each UL carrier.<br><br>(3GPP TS 38.300 v17.2.0, § 7.8)<br><br>**6.10 Bandwidth Adaptation**<br><br>With Bandwidth Adaptation (BA), the receive and transmit bandwidth of a UE need not be as large as the bandwidth of the cell and can be adjusted: the width can be ordered to change (e.g. to shrink during period of low activity to save power); the location can move in the frequency domain (e.g. to increase scheduling flexibility); and the subcarrier spacing can be ordered to change (e.g. to allow different services). A subset of the total cell bandwidth of a cell is referred to as a Bandwidth Part (BWP) and BA is achieved by configuring the UE with BWP(s) and telling the UE which of the configured BWPs is currently the active one.<br><br>Figure 6.10-1 below describes a scenario where 3 different BWPs are configured:<br><br>- $BWP_1$ with a width of 40 MHz and subcarrier spacing of 15 kHz; |

| Claim 10 | Public Documentation |
|---|---|
| | - $BWP_2$ with a width of 10 MHz and subcarrier spacing of 15 kHz;<br>- $BWP_3$ with a width of 20 MHz and subcarrier spacing of 60 kHz.<br>  <br>**Figure 6.10-1: BA Example**<br><br>(3GPP TS 38.300 v17.2.0, § 6.10)<br><br>In the example above, $BWP_3$ is a non-limiting example of a first frequency spectrum resource, and $BWP_1$ is a non-limiting example of a second frequency spectrum resource. |
| [10b] a processor coupled to the quality status module and configured to: | The Accused Instrumentalities comprise a processor coupled to the quality status module.<br><br>*See* elements below. |
| [10c] determine, based on the quality status of the first frequency spectrum resource, that the first frequency spectrum resource is a sub-optimal resource, for the uplink channel and the downlink channel, relative to other frequency spectrum resources that are available for use by the wireless base station; and | The processor(s) in the Accused Instrumentalities are configured to determine, based on the quality status of the first frequency spectrum resource, that the first frequency spectrum resource is a sub-optimal resource, for the uplink channel and the downlink channel, relative to other frequency spectrum resources that are available for use by the wireless base station.<br><br>For example, the preferred frequency is selected dynamically based on mobile reported measurements. Close to the base station, ”second frequency resource” (TDD) is preferred and used for both uplink and downlink transmissions, and ”first frequency resource” (SUL) is not used.<br><br>One example of this determination is the handover mechanism to add/remove SUL component carriers (SCells). |

| Claim 10 | Public Documentation |
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## B.1 Supplementary Uplink

To improve UL coverage for high frequency scenarios, SUL can be configured (see TS 38.101 [18]). With SUL, the UE is configured with 2 ULs for one DL of the same cell as depicted on Figure B.1-1 below:

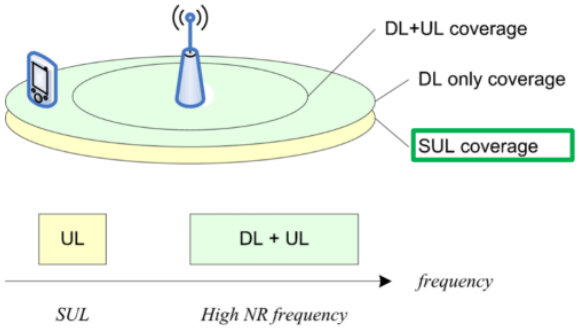


**Figure B.1-1: Example of Supplementary Uplink**

(3GPP TS 38.300 V2.0.0 (2017-12), § B.1).

As a further and/or alternative example, the preferred frequency is selected dynamically based on mobile service requirements (e.g. BW) and activity.

## 6.10 Bandwidth Adaptation

With Bandwidth Adaptation (BA), the receive and transmit bandwidth of a UE need not be as large as the bandwidth of the cell and can be adjusted: the width can be ordered to change (e.g. to shrink during period of low activity to save power); the location can move in the frequency domain (e.g. to increase scheduling flexibility); and the subcarrier spacing can be ordered to change (e.g. to allow different services). A subset of the total cell bandwidth of a cell is referred to as a Bandwidth Part (BWP) and BA is achieved by configuring the UE with BWP(s) and telling the UE which of the configured BWPs is currently the active one.

Figure 6.10-1 below describes a scenario where 3 different BWPs are configured:

- $BWP_1$ with a width of 40 MHz and subcarrier spacing of 15 kHz;

(3GPP TS 38.300 v17.2.0, § 6.10)

As is well-known in the industry, different mobile services may require different bandwidths. The service bandwidth requirement is a non-limiting example of the quality metric that the allocated spectrum has to meet (to provide the required throughput for the service).

| Claim 10 | Public Documentation |
|---|---|
| | In the example above, the base station determines that the first frequency spectrum resource ($BWP_3$) with 20MHz of bandwidth does not have sufficient bandwidth and, therefore, is sub-optimal when compared to the second frequency spectrum resource ($BWP_1$) with 40 MHz. |
| [10d] in response to the determination that the first frequency spectrum resource is the sub-optimal resource, assign the first frequency spectrum resource to a shared resource pool; and | The processor(s) in the Accused Instrumentalities are configured to in response to the determination that the first frequency spectrum resource is the sub-optimal resource, assign the first frequency spectrum resource to a shared resource pool.<br><br>For example, the handover mechanism referred to previously is used to add/remove second component carrier (SCells). In handover, UE measurements are used to decide on the best serving cell, or carrier in CA. The same mechanism as CA is used for adding/removing SUL. Previously it was shown that gNB is responsible for making radio resource decisions. By default, all available frequency resources are in a "Shared Resource Pool." |

## B.1 Supplementary Uplink

To improve UL coverage for high frequency scenarios, SUL can be configured (see TS 38.101 [18]). With SUL, the UE is configured with 2 ULs for one DL of the same cell as depicted on Figure B.1-1 below:

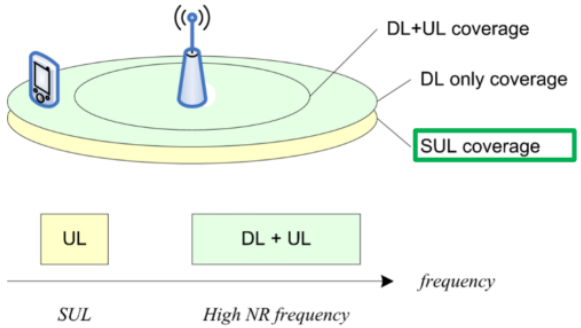


**Figure B.1-1: Example of Supplementary Uplink**

(3GPP TS 38.300 V2.0.0 (2017-12), § B.1).

## 7.7 Carrier Aggregation

When CA is configured, the UE only has one RRC connection with the network. At RRC connection establishment/re-establishment/handover, one serving cell provides the NAS mobility information, and at RRC connection re-establishment/handover, one serving cell provides the security input. This cell is referred to as the Primary Cell (PCell). Depending on UE capabilities, Secondary Cells (SCells) can be configured to form together with the PCell a set of serving cells. The configured set of serving cells for a UE therefore always consists of one PCell and one or more SCells.

The reconfiguration, addition and removal of SCells can be performed by RRC. At intra-NR handover, RRC can also add, remove, or reconfigure SCells for usage with the target PCell. When adding a new SCell, dedicated RRC signalling is used for sending all required system information of the SCell i.e. while in connected mode, UEs need not acquire broadcast system information directly from the SCells.

(3GPP TS 38.300 V2.0.0 (2017-12), § 7.7).

As a further and/or alternative example, the first frequency spectrum resource may be a bandwidth part:

| Claim 10 | Public Documentation |
|---|---|
| | **4.4.5 Bandwidth part**<br><br>A bandwidth part is a subset of contiguous common resource blocks defined in subclause 4.4.4.3 for a given numerology $\mu_i$ in bandwidth part on a given carrier. The starting position $N_{\mathrm{BWP},i}^{\mathrm{start},\mu}$ and the number of resource blocks $N_{\mathrm{BWP},i}^{\mathrm{size},\mu}$ in a bandwidth part shall fulfil $N_{\mathrm{grid},x}^{\mathrm{start},\mu} \le N_{\mathrm{BWP},i}^{\mathrm{start},\mu} < N_{\mathrm{grid},x}^{\mathrm{start},\mu} + N_{\mathrm{grid},x}^{\mathrm{size},\mu}$ and $N_{\mathrm{grid},x}^{\mathrm{start},\mu} < N_{\mathrm{BWP},i}^{\mathrm{start},\mu} + N_{\mathrm{BWP},i}^{\mathrm{size},\mu} \le N_{\mathrm{grid},x}^{\mathrm{start},\mu} + N_{\mathrm{grid},x}^{\mathrm{size},\mu}$, respectively. Configuration of a bandwidth part is described in clause 12 of [5, TS 38.213].<br><br>A UE can be configured with up to four bandwidth parts in the downlink with a single downlink bandwidth part being active at a given time. The UE is not expected to receive PDSCH, PDCCH, or CSI-RS (except for RRM) outside an active bandwidth part.<br><br>A UE can be configured with up to four bandwidth parts in the uplink with a single uplink bandwidth part being active at a given time. If a UE is configured with a supplementary uplink, the UE can in addition be configured with up to four bandwidth parts in the supplementary uplink with a single supplementary uplink bandwidth part being active at a given time. The UE shall not transmit PUSCH or PUCCH outside an active bandwidth part. For an active cell, the UE shall not transmit SRS outside an active bandwidth part.<br><br>Unless otherwise noted, the description in this specification applies to each of the bandwidth parts. When there is no risk of confusion, the index $\mu$ may be dropped from $N_{\mathrm{BWP},i}^{\mathrm{start},\mu}$, $N_{\mathrm{BWP},i}^{\mathrm{size},\mu}$, $N_{\mathrm{grid},x}^{\mathrm{start},\mu}$, and $N_{\mathrm{grid},x}^{\mathrm{size},\mu}$.<br><br>(3GPP TS 38.211 v17.2.0, § 4.4.5)<br><br>As referenced above, out of the maximum of 4 assigned bandwidth parts, the UE can only operate in a single BWP at any given time. Previously it was shown that the base station is responsible for making radio resource decisions. By default, all available frequency resources are in a shared resource pool. If UE is instructed to move to a new bandwidth part, the old bandwidth part is reassigned to the shared resource pool. |
| [10e] a scheduler module coupled to the processor and configured to: | The Accused Instrumentalities comprise a scheduler module coupled to the processor.<br><br>For example, the Accused Instrumentalities comprise a specific hardware or software structure corresponding to the claimed scheduler module. For example, 3GPP documents specify base station messages for scheduling the frequency resource that is used. |